Cleanup Methods for Petroleum-Contaminated Soil and Groundwater
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A number of technologies are available to clean up, or remediate, soil and groundwater contaminated by leaking underground storage tanks. Methods which treat soil in place are known as in situ treatments. Other methods require excavating soil and transporting it off-site for treatment. Quite often, more than one technology is appropriate at a site. Which methods are best for cleaning up a particular site depend upon such factors as cost, speed, disruption of the site, physical layout, and the ability of the method to meet cleanup criteria.

In Situ Soil Remediation Methods

Because in situ remediation treats soil in place, it has the advantage of causing minimal disruption to a site. Additionally, in situ treatment is often less costly than excavating soil for treatment off-site. In situ methods may have to be in place for years to complete a cleanup. In situ methods are typically used on projects where more than 100 cubic yards of soil have been contaminated, and they work best on sandy or gravelly soils.

Soil Venting
Soil venting involves installing a shallow well or series of wells in the soil and using a blower to pump air out of the soil. The air flowing through the soil evaporates volatile contaminants from the soil and increases oxygen in the soil, which can promote biodegradation. The volatile compounds are then either discharged to the atmosphere or removed from the air stream by a treatment device. The aboveground equipment consists primarily of a blower, and possibly a water trap. Depending upon contamination levels, an air treatment device may also be necessary. Generally, a site can be remediated within a few years. However, remediation may take longer at heavily contaminated sites or at sites with diesel or fuel oil contamination.

In Situ Soil Bioremediation
Bioremediation is a technology in which petroleum compounds are broken down by naturally occurring bacteria in the soil. The contaminants are reduced to carbon dioxide and water, or other compounds incorporated into bacterial cells. The process may take one or more years to clean up a site. In general, the equipment at a site includes a blower system similar to that used for soil venting, which is used to increase oxygen levels in the soil. Also, an infiltration system may be used to provide nutrients to the bacteria and maintain moisture levels. Prior DNR approval to add nutrients or water is necessary.

Passive Bioremediation
At sites where conditions are suitable, the naturally occurring biodegradation of contaminants can be used to essentially let a site clean up itself without taking more active measures. In such cases, the costs involved are only for progress monitoring. Since naturally

occurring rates of biodegradation are relatively slow, this approach may take several to many years to clean up a site. Since no actions are taken to speed up the process, this approach is more suitable at sites with relatively low levels of contamination where cleanup can occur in a reasonable period of time.

Other In Situ Remediation Methods

Other methods for in situ treatment include: in situ soil washing, steam stripping, and thermal-enhanced soil venting. These methods tend to be expensive and may be limited to cases with unusual circumstances.

Remediation Methods for Excavated Soil

Disposal at Asphalt Plants

Contaminated soil may be excavated and transported to approved asphalt plants where the soil is added to the asphalt mix. Asphalt plants must have air management permits to accept petroleum-contaminated soil, and the permits may limit the amount of contaminated soil a plant may accept. Generally, asphalt plants prefer soil with a high sand content. Asphalt incorporation can be costly due to the high cost of transporting and processing the soil. Additionally, contaminated soil may have to be stored on-site for up to a month while soil samples are sent to laboratories for chemical analysis required by asphalt plants. Since the soil is removed from the site, clean soil is needed to fill the excavation. The DNR maintains a list of approved asphalt plants and mobile soil remediation units.

Thin Spreading

In thin spreading, contaminated soil is spread out on a water-tight surface, such as pavement or fiber-reinforced plastic, and the volatile compounds in the soil are allowed to evaporate. Usually, soil is spread out in a layer less than one-foot deep for a period of two or more months. In some cases, nutrients and moisture are added to increase biodegradation. Air management rules regulate the rate at which volatile compounds can be evaporated into the atmosphere. The advantages to using thin spreading as a cleanup method are that it is one of the most economical means of cleaning soils with low levels of petroleum contamination, and it works well with all soil types. A disadvantage to using this method is the large area needed to treat large quantities of soil.

Thermal Desorption

In thermal desorption, the soil is heated up or "roasted," then contaminants evaporate from the contaminated soil. The vapors from evaporation are then burned in a vapor-treatment device. An important advantage of thermal desorption is that soil is cleaned up quickly and can be used to fill in the excavation. A disadvantage to using this method is the amount of space required at the site to set up the equipment and stockpile soils. The department maintains a list of thermal desorption units that treat contaminated soil.

Bioremediation/Biopile Remediation

Bioremediation may also be used to treat contaminated soils that are excavated, this is called a biopile. The soil is piled on an impervious surface and a plastic cap is placed over the pile. Air is pumped through the soil and nutrients may be added to promote breakdown of the contaminants.

Disposal in Landfills

Contaminated soils can be excavated and transported to sanitary landfills for disposal. Due to requirements for landfill design and operation, only a small number of landfills are currently accepting contaminated soil. As with disposal at asphalt plants, soil may have to be stored on-site while samples are being analyzed. Disposing of soil in a landfill can be very costly due to transportation costs and landfill tipping fees. Most landfills maintain records of who disposed of wastes in the landfill. Tank owners and operators, as generators of contaminated soils, may be legally liable for investigation and cleanup costs at landfills where they disposed of contaminated soils.

Other Methods

Other methods include: soil washing and bioremediation in a slurry reactor. These technologies may become more prevalent in the future as they become more cost-effective. These technologies can be used on-site, or the soil can be transported off-site to a treatment system.

Product Recovery Methods

Product recovery involves physically pumping the petroleum product from the top of the water table. Pumping product separately from contaminated groundwater is only effective when a large amount of product has been lost. Product recovery is almost always conducted simultaneously with groundwater pumping. The product is stored on-site temporarily in a product tank and periodically trucked off-site to be recycled. Generally, some of the collection and separation equipment is housed in a small shed oil-site.

Groundwater Remediation

Groundwater Extraction

Generally, groundwater remediation involves pumping contaminated groundwater to the surface for treatment before discharging to surface waters. Recovery wells ranging from 4 to 24 inches in diameter are used to pump water to the surface. The depth of a well depends on site conditions. In some very fine-grained soils, like clay or silt, a trench system may improve the flow of contaminated groundwater to a recovery well. In these cases, a trench is cut into the soil and backfilled with gravel into which a well is installed. The recovery well is usually housed under a small enclosure. However, if necessary, the top of the well and associated piping can be installed under a manhole in locations such as parking lots and driveways. Depending upon the extent of contamination, a number of methods can be used to treat contaminated ground water.

Groundwater Treatment by Air Stripping

Air stripping is a process that transfers volatile organic compounds from water to air. There are two common methods of air stripping to clean up contaminated groundwater. In the first method, a tower is constructed in which contaminated groundwater drips downward through an air stream flowing upward. The tower is filled with a specially designed, permeable material called packing. The packed tower is usually less than 3 feet in diameter, but the tower may be 15 to 30 feet tall. The second method involves bubbling high pressure air through contaminated water in a tank system. The tank is typically located inside a small shed. There are specific advantages and disadvantages for each type of air stripping, so systems should be designed on a site-specific basis. Pumping rates, level of contamination, and other factors determine the system design. Air monitoring is required. Following treatment, the water is usually discharged to a surface water body, which requires a wastewater discharge permit.

Groundwater Treatment by Granular Activated Carbon Filtering

Contaminated groundwater can be pumped through a granular activated carbon filter that traps contaminants. The carbon in the filter eventually becomes saturated and ineffective at cleaning the groundwater. When that happens, the carbon is replaced and the old carbon is disposed of or regenerated. Again, pumping rates, contamination levels, and other factors determine the system design. Following treatment, the water is usually discharged to a surface water body. This action also requires a wastewater discharge permit.

Groundwater Pumping and Sanitary Sewer Disposal

At sites with very low pumping rates, the most cost-effective means to dispose of contaminated groundwater may be to discharge the water directly into the sanitary sewer system for treatment at the Publicly Owned Treatment Works (POTW). In order to discharge into the sanitary sewer, the contaminated water will have to meet the POTW's standards for acceptable levels of contamination. Occasionally, no on-site treatment is needed. However, sites with heavily contaminated groundwater may require on-site pretreatment to bring the pumped water to acceptable standards. Initial project costs for POTW treatment are typically very low compared to other treatment methods because treatment equipment does not always need to be purchased and installed at the site. Prior approval from the POTW is necessary. The costs-per-gallon are typically quite high, compared to on-site treatment, because there is a fee for discharging contaminated groundwater to the sanitary sewer. Discharge fees may result in POTW treatment not being cost-effective on larger projects with high pumping rates.

Air Sparging

Air sparging is a process where air is pumped into the groundwater. The air then aerates the water much like an air stripper. This method works best at sandy sites and cannot be used at sites where there are layers of sand and clay. In almost all cases, a soil venting system is used with an air sparging system to extract the vapors.

In Situ Groundwater Bioremediation

Bioremediation is a technology in which petroleum compounds are broken down by naturally occurring bacteria in groundwater. The contaminants are reduced to carbon dioxide and water which are incorporated into bacterial cells. The process may take one or more years to clean up a site. A groundwater extraction well and an infiltration system may be used to provide nutrients to the bacteria, maintain moisture levels, and carry oxygen to groundwater. Prior DNR approval to add nutrients or water is necessary.

Groundwater Treatment by Other Methods

Other methods for groundwater treatment include: ultraviolet radiation, use of bioreactors, and reverse osmosis for metals contamination.

Containment Methods

Containment might be used on very large sites where the cleanup costs would be extremely expensive, where there is no feasible cleanup technology, and where there is little risk of contamination migrating to groundwater. Containment is essentially building a barrier around the contamination with impermeable walls constructed into trenches and sealing the ground surface to prevent infiltration. Since containment permanently restricts future land use, it is only used when there is little or no risk of the contamination spreading after containment, when technology to clean up a site is limited, and the cost to remove the contamination would be many millions of dollars. Prior DNR approval is required.

Using More Than One Remediation Technology

More than one technology is often used at a site. As an example, a small site with no groundwater contamination may use asphalt disposal for the soils that were adjacent to the tank locations and soil venting for the rest of a site. A heavily contaminated site that has groundwater contamination may include: product recovery, one or two different technologies for soil cleanup, and one or two different technologies for groundwater cleanup. There is no generic plan that is perfect for all sites. Each site has different conditions that require remediation to be designed specifically for that site.